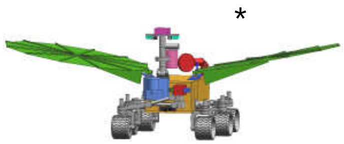
Mars Sample Return Discussions

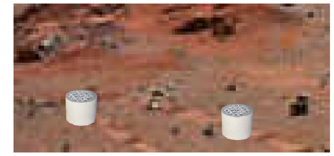
As presented on February 23, 2010

*Mars Sample Return is conceptual in nature and is subject to NASA approval. This approval would not be granted until NASA completes the National Environmental Policy Act (NEPA) process.

Functional Steps Required to Return a Scientifically Selected Sample to Earth



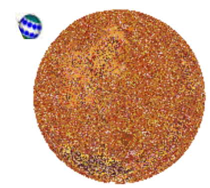
Sample Caching Rover (MAX-C) *



Sample Canisters On Mars Surface *

1. Launch from Earth/Land on Mars
2. Select Samples
3. Acquire/Cache Samples

** Mars Sample Return Lander *



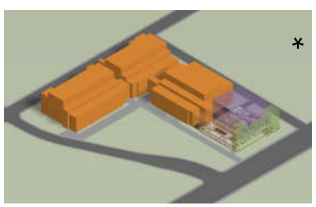
Orbiting Sample (OS) in Mars Orbit *

4. Retrieve/Package Samples on Mars
5. Launch Samples to Mars Orbit

** Mars Sample Return Orbiter *

Orbiting Sample (OS) On Earth

6. Capture and Isolate Sample Container
7. Return to Earth
8. Land on Earth



Mars Returned Sample Handling (MRSH) Facility *

Sample Science

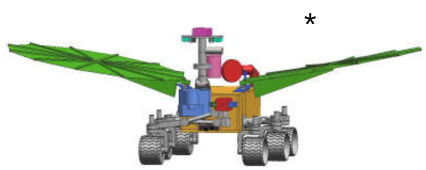
9. Retrieve/Quarantine and Preserve Samples on Earth
10. Assess Hazards
11. Sample Science

**Note: Launch sequence of MSR-L/MSR-L can be switched: launching MSR-O first can provide telecom relay support for EDL/surface operation/MAV launch

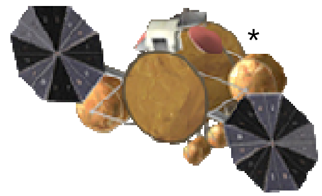
*Artist's Rendering

"For Planning and Discussion Purposes Only"

Multi-Element Architecture for Returning Samples from Mars Is a Resilient Approach

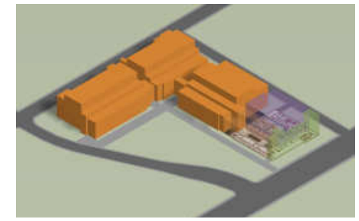


MAX-C (Caching Rover)



Mars Sample Return Orbiter

Mars Sample Return Lander



Mars Returned Sample Handling

Science robustness

- Allows robust duration for collection of high quality samples

Technical robustness

- Keeps landed mass requirements in family with MSL Entry/Descent/Landing (EDL) capability
- Spreads technical challenges across multiple elements

Programmatic robustness

- Involves mission concepts with sizes similar to our implementation experience
- Incremental progress with samples in safe, scientifically intact states: improved program resiliency
- Spreads budget needs and reduces peak year program budget demand
- Leverages and retains EDL technical know-how

*Artist's Rendering

Mars Astrobiological Explorer-Cacher (MAX-C) rover

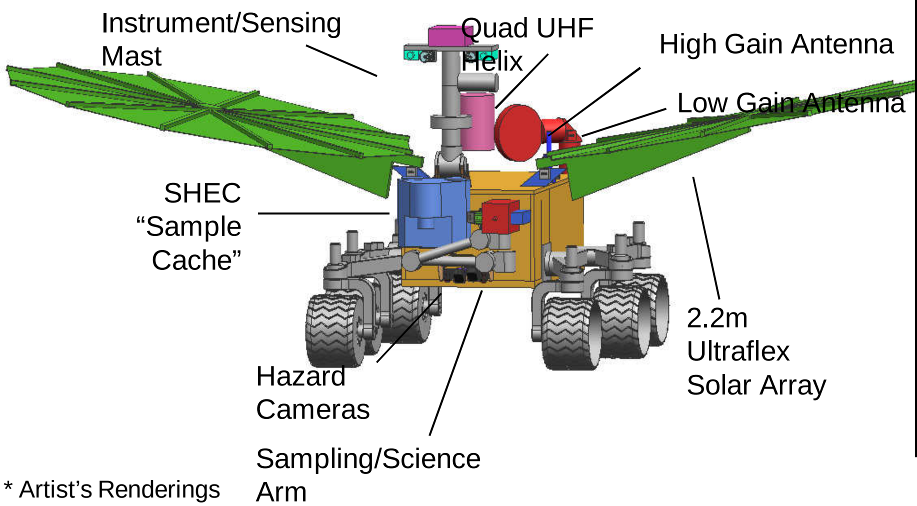
MAX-C rover will perform *in situ* exploration of Mars and acquire/cache dual sets of scientifically selected samples

- Team X conducted Decadal Survey Mars Panel study in Jan'10: added dual cache

Major Rover Attributes	
Science Capability	Remote and contact science: Color stereo imaging, macro/micro-scale mineralogy/composition, micro-scale organic detection/characterization, micro-scale imaging Coring and caching rock samples for future return
Payload Mass	~15 kg instruments ~60 kg including corer/abrader, dual cache, mast, arm
Traverse Capability	20 km (design capability)
Surface Lifetime	500 Sols (design life)

Key mission concept features

- Cruise/EDL system derived from MSL, launched on Atlas V 531 class vehicle.
- Land in ~10 km radius landing ellipse, up to -1 km altitude, within +25 to -15 degrees latitude.
- 43% mass margin carried on MAX-C rover (adopting many MSL parts), landing platform, and hardware where specific modifications would be made to the MSL EDL system.



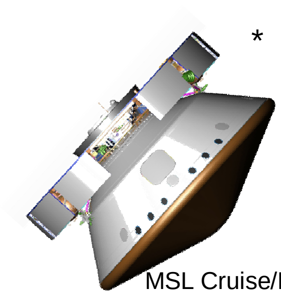
* Artist's Renderings

MAX-C Rover	360
ExoMars Rover * (agreed not to exceed)	300
Platform	330
Landed Systems	**990 kg**
Entry Vehicle (Descent Stage and Aeroshell)	2360
Descent Stage Propellant	500
Entry Vehicle (wet, and including cruise/entry balance mass)	**2860 kg**
Cruise Stage Propellant	90
Cruise Stage (dry)	500
Cruise Stage (wet)	**590 kg**
Total Launch Mass (with margin)	**4440 kg**

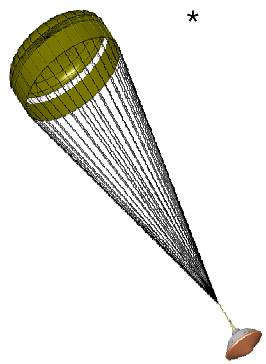
Current 2018 Mission Concept Implementation Approach

Land MAX-C and ExoMars rovers together attached to a landing platform

- MAX-C and ExoMars rovers perform *in situ* science exploration: assessing potential joint experiments
- MAX-C will cache scientifically selected samples for future return

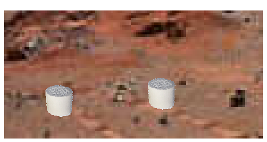


MSL Cruise/EDL and Skycrane system lands Rovers on platform

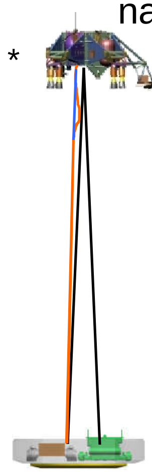


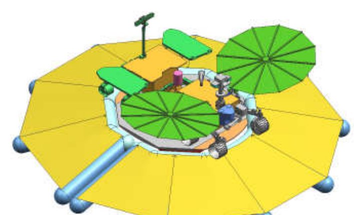
Team X study concept included:

- Landing platform (pallet): 'proof-of-concept' by Team X; with further refinements by dedicated design team
- Scaling of MSL aeroshell diameter (from 4.5 m to 4.7 m) to accommodate 2 rovers
  - Preserve MSL shape, L/D
  - Same thermal protection system
  - Same parachute
- Descent stage architecture/design based on MSL
  - Same MSL engines, avionics, radar, algorithms, etc
  - Mechanical structure updated to accommodate rovers/platform geometry/loads
  - Incorporates terrain-relative descent navigation capability



Sample Canisters On Mars Surface





Rovers post-landing w/ example egress aids

* Artist's Renderings

* Artist's Renderings

"For Planning and Discussion Purposes Only"

Mars Sample Return Orbiter Concept

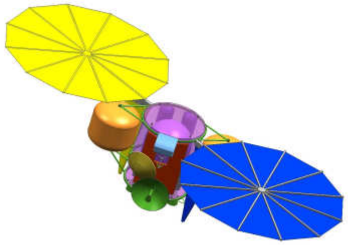
MSR Orbiter will

- Rendezvous with Orbiting Sample (OS) container in 500km orbit.
- Capture, transfer and package OS into Earth Entry Vehicle (EEV)
- Perform "break-the-chain" of contact with Mars
- Return to Earth
- Release EEV for entry
- Divert into a non-return trajectory

If Before MSR Lander

- Monitor critical events of EDL and MAV launch
- Provide telecomm relay for lander and rover

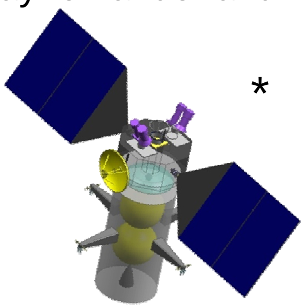
*



Team-X Design:

No "staging" required

*



Alternate Design:

Separate prop stage that separates after Trans Earth Injection

* Artist's Renderings

Key mission concept features

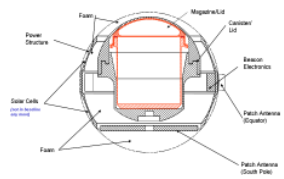
- Over twice the propellant needed by typical Mars orbiters. Uses bi-prop systems flown on previous Mars missions
- UHF Electra relay system for surface relay
- Orbiter mass quite dependent on specific launch and return years. Designed to envelop opportunities in early-mid 2020s.

EEV		**50 kg**
Orbiter Systems	Rendezvous systems	20
	Capture/Sample Transfer	40
	Avionics	40
	Power	130
	Structures/Mechanisms	330
	Cabling	40
	Telecom	30
	Propulsion	170
	Thermal	40
	Misc. Contingency	100
	TOTAL Orbiter Systems Mass	**940 kg**
Propellant		2280 kg
TOTAL (43% margins)		**3270 kg**

"For Planning and Discussion Purposes Only"

MSR Orbiter: Sample Capture/Earth Entry Vehicle (EEV)

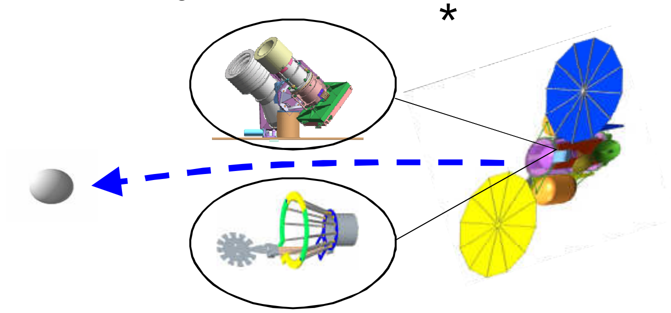
Capture Basket concept testing on NASA C-9 zero-g aircraft



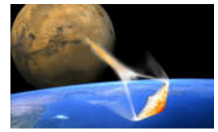
*

Orbiting Sample (OS) container

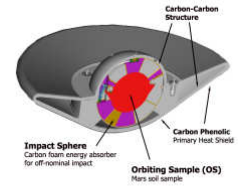
*

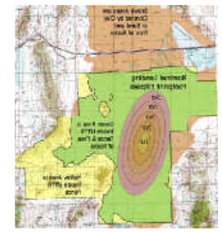


*



*





Detection and rendezvous systems

- OS released into a 500km circular orbit by the MAV
- Optical detection from as far as 10,000km.
- Autonomous operation for last tens of meters

Capture System

- Capture basket concept designed
- Prototype demonstrated on NASA zero-g aircraft campaign.

Strawman EEV design

- 0.9m diameter, 60° sphere-cone blunt body
- Self-righting configuration
- No parachute required
- Hard landing on heatshield structure, with crushable material surrounding OS

Capitalizes on design heritage

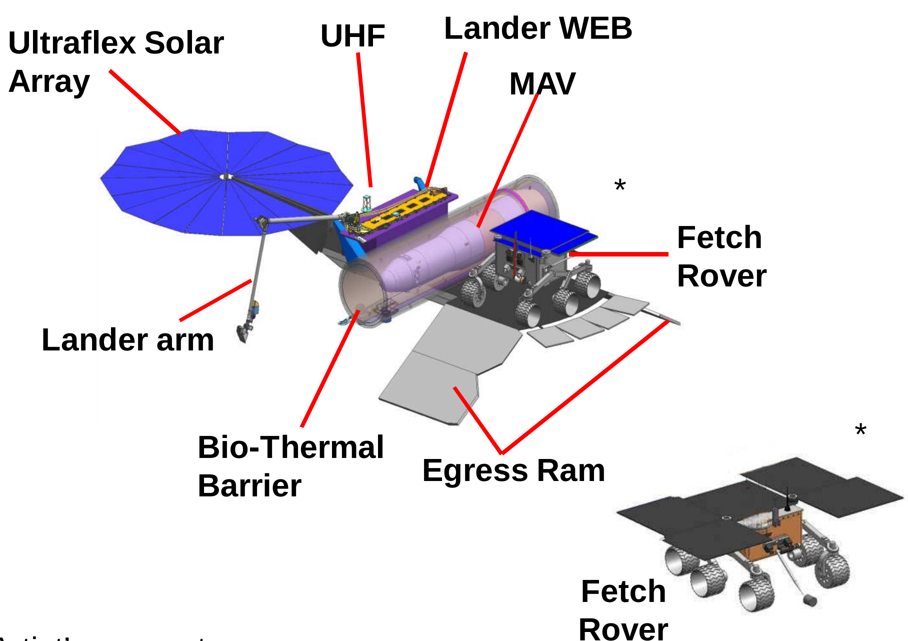
- Extensive aero-thermal testing and analysis
- Wind tunnel tests verified self-righting

* Artist's Renderings

Mars Sample Return Lander Concept

MSR Lander will

- Land a pallet with Mars Ascent Vehicle (MAV) and fetch rover
- Upon safe landing, the fetch rover will egress and retrieve MAX-C sample cache
  - Traverse distance up to ~14 km
- Sample cache transferred by robotic arm on pallet from fetch rover to MAV
- MAV will launch sample container into stable Martian orbit



*Artist's concept

Key mission concept features

- MSR lander pallet delivered to the surface via the Skycrane EDL approach
- Supports and protects MAV in thermal igloo and minimizes thermal cycle depths
- 1 Earth year life

MAV		**300 kg**
Rover		**160 kg**
Live Lander	Cameras	5
	ACS	10
	CDH	15
	Power	65
	Telecon	15
	Cabling	50
	Thermal	35
	Struct (prim,secondary,other)	170
	MAV Igloo and Erection	60
	Rover Support (ramps, lift, etc.)	40
	Sampling Arm (and bio-barrier)	10
	Sample Handling and Pkg	20
	Misc. contingency	65
	Lander Total	**560 kg**
TOTAL (43% margins)		**1020 kg**

"For Planning and Discussion Purposes Only"

Mars Returned Sample Handling Element

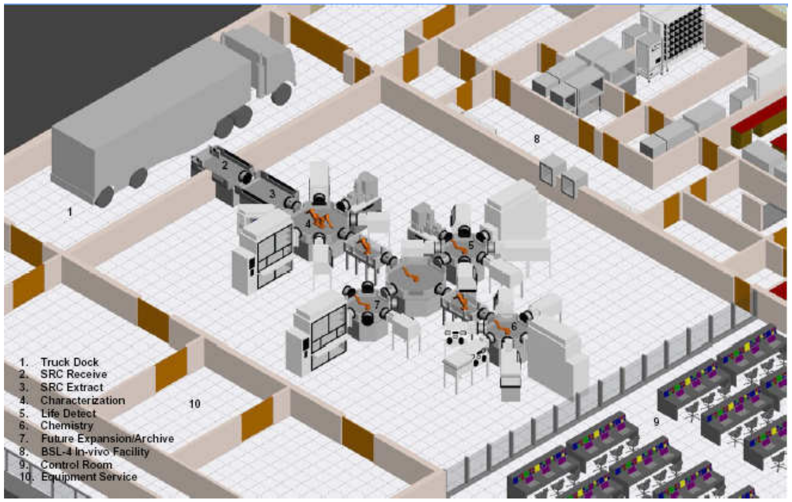
Mars Returned Sample Handling element includes: ground recovery operations; Sample Receiving Facility (SRF) and sample curation facility

The SRF will

- Contain samples as if potentially hazardous, equivalent to biosafety level-4 (BSL-4).
- Keep samples isolated from Earth-sourced contaminants
- Provide capability to conduct biohazard test protocol as a prerequisite to release of samples from containment.
- Could serve as a sample curation facility after hazard assessment.

Industry studies performed to scope facility and processes (2003)

- 3 architectural firms, with experience in biosafety, semi-conductor and food industries.
- Current costs estimates and scope based on studies and comparison to existing BSL-4 facilities.



Artist's concept of an SRF

Sample Acquisition and Encapsulation

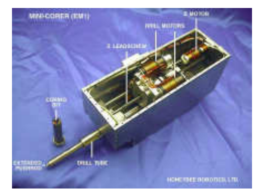
Target Science Requirements*

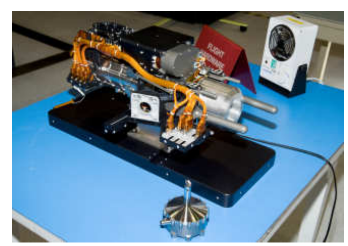
- Acquire~ 20 rock cores with dimension approximately 1 cm wide by 5 cm long
- Store and seal samples in individual tubes
- Provide capability to reject a sample after acquisition
- Measure the sample volume or mass with 50% accuracy

Examples of acceptable samples

Current Capabilities/State of the Art

- Two flight-like corers developed by Honeybee Robotics:
  - Mini Corer (for ’03/‘05 MSR)
  - CAT (for MSL) in 2006.
- MSL flight drill developed and tested





*Consistent with MEPAG Next Decade Science Analysis Group (ND-SAG)

Mars Ascent vehicle (MAV)

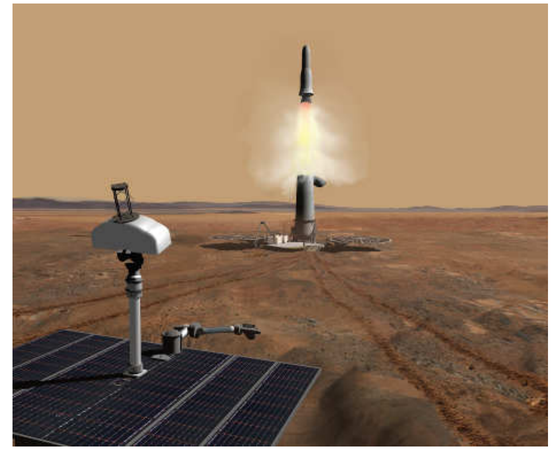
Target Requirements

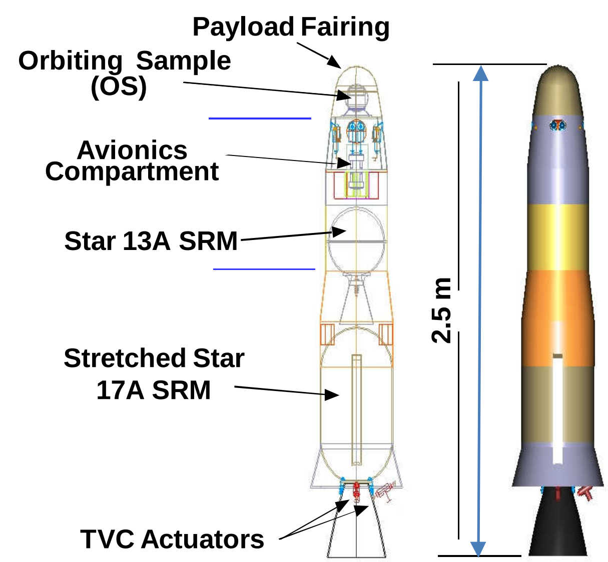
- Launches 5kg Orbiting Sample (OS) into 500+/-100 km orbit, +/-0.2deg
- Ability to launch from +/- 30º latitudes
- Continuous telemetry for critical event coverage during ascent.
- Survive relevant environment for Earth-Mars Transit, EDL, and Mars surface environment for up to one Earth year on Mars

Current Capabilities/State of the Art

- NASA has not launched a rocket from a planetary surface autonomously before.
- MAV components are available, but are not developed for long-term storage in relevant environments (including thermal cycling) or for EDL g-loads.
- Mass estimate assessment ~300 kg

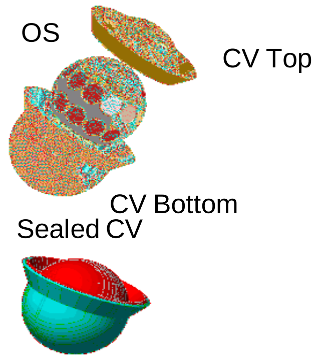
All figures are artist's concepts





* LMA 2002 study

Back Planetary Protection



Target Requirement

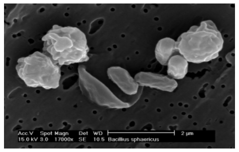
- MSR is a Restricted Earth Return mission
- Goal of $<10^{-6}$ chance of inadvertent release of an unsterilized >0.2 micron Mars particle.

Current Capabilities/State of the Art

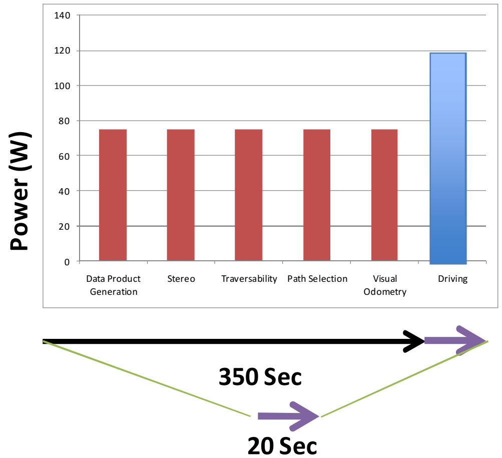
- Probabilistic Risk Analysis (PRA) approach was developed to assess the overall probability of meeting the goal
- Preliminary design of the EEV was completed and a test article developed. Performed component and system tests
- A brazing technique was developed to TRL 3 for containment assurance and breaking the chain of contact with Mars
- A leak detection concept was developed to TRL 3

Other Key Challenges

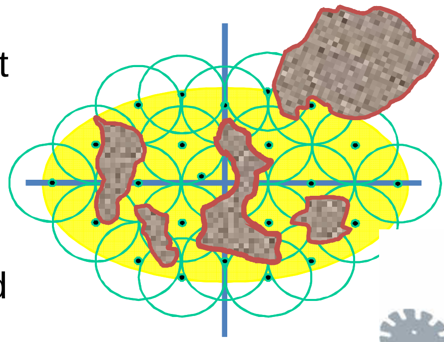
- Round trip planetary protection (MAX-C)
  - <u>Objective:</u> Avoid false positive life detection
  - <u>Approach:</u> Clean assembly, bio-barrier, analytical tool to compute overall probability of contamination
- Mobility capability (MAX-C and MSR fetch rover)
  - <u>Objectives:</u> Increase average rover speed and develop lighter/smaller motor controller
  - <u>Approach:</u> Use FPGAs as co-processors and develop distributed motor control
- Terrain-relative descent navigation (MAX-C and MSR lander)
  - <u>Objective:</u> Improved landing robustness
  - <u>Approach:</u> Use terrain-relative navigation approach for avoiding landing hazards. Leverage NASA ALHAT project
- Rendezvous and sample capture (MSR orbiter)
  - <u>Objective:</u> Locate, track, rendezvous, and capture OS in Mars orbit
  - <u>Approach:</u> Update system design, develop testbeds, and perform tests. Leverage Orbital Express capability



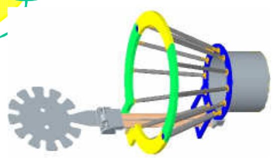
Round Trip PP



50 cm rover move timeline



Safe Landing



Sample Capture

"For Planning and Discussion Purposes Only"

Summary

- Strong scientific impetus for sample return
  - Next major step in understanding Mars and the Solar System
- Engineering readiness for sample return
  - Past investments have developed key capabilities critical to sample return
  - Key remaining technical challenges/development are identified
- Resilient multi-flight-element approach
  - Science robustness
    - Allows proper sample selection/acquisition
  - Technical robustness
    - Spreads technical challenges across multiple elements
    - Keeps landed mass requirements in family with MSL EDL capability
  - Programmatic robustness
    - Involves concepts similar to our existing implementation experience
    - Scientifically intact samples on/around Mars that provides program resiliency
    - Spreads budget needs over ~1.5 decade
    - Approach amenable to international partnership
- Multi-element MSR should not be viewed as an "isolated (flagship) mission" but as a cohesive campaign that builds on the past decade of Mars exploration